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The Simplified PADUA REnal (SPARE) nephrometry system: a novel classification of parenchymal renal tumours suitable for partial nephrectomy

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Objective

To simplify the original Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) classification of renal tumours, generating a new system able to predict equally or better the risk of overall complications in patients undergoing partial nephrectomy (PN); and to test if the addition of the contact surface area (CSA) parameter improves the accuracy of the original PADUA and new Simplified PADUA REnal (SPARE) nephrometry classification systems.

Patients and Methods

We analysed the clinical records of 531 patients who underwent PN (open, laparoscopic and robot-assisted) for renal tumours at five tertiary academic referral centres from January 2014 to December 2016. The ability of each variable included in the PADUA classification to predict overall complications was tested using binary logistic regression analysis. The variables that were not statistically significant were excluded from the SPARE classification. In addition to the original PADUA and SPARE systems, another two models were generated adding tumour CSA. Receiver operating characteristic curve analysis was used to compare the ability of the four different models to predict overall complications. Binary logistic regression was used to perform both univariable and multivariable analyses looking for predictors of postoperative complications. Linear regression analysis was used to identify independent predictors of absolute change in estimated glomerular filtration rate (eGFR; ACE).

Results

The SPARE nephrometry score system including: (i) rim location, (ii) renal sinus involvement, (iii) exophytic rate, and (iv) tumour dimension; showed equal performance in comparison with the original PADUA score (area under the curve [AUC] 0.657 vs 0.664). Adding tumour CSA to the original PADUA (AUC 0.661) or to the SPARE (AUC 0.658) scores did not increase the accuracy of either system to predict overall complications. The SPARE system (odds ratio 1.2, 95% confidence interval 1.1–1.3) was an independent predictor of postoperative overall complications. Age ($P < 0.001$), body mass index ($P < 0.001$), Charlson Comorbidity Index ($P = 0.02$), preoperative eGFR ($P < 0.001$), and tumour CSA ($P = 0.005$) were independent predictors of ACE. Limitations include the retrospective design and the lack of central imaging review.

Conclusions

The new SPARE score is comprised of only four variables instead of the original six and its accuracy to predict overall complications is similar to that of the original PADUA score. Addition of tumour CSA was not associated with an increase in prognostic accuracy. The SPARE system could replace the original PADUA score to evaluate the complexity of tumours suitable for PN.

Keywords

renal cell carcinoma, partial nephrectomy, nephrometry scores, perioperative outcomes, pathological features

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Introduction

The European Association of Urology (EAU) guidelines on RCC suggest the use of nephrometry systems to predict objectively the potential morbidity of nephron-sparing surgery for renal masses [1]. These tools provide important data for treatment planning, patient counselling, and comparison between different partial nephrectomy (PN) series [2].

The R.E.N.A.L. (Radius; Exophytic/Endophytic; Nearness; Anterior/Posterior; Location) nephrometry score and Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) classification were proposed in 2009 and widely used thereafter [3,4]. Several studies externally validated both systems as predictors of overall complications, warm ischaemia time (WIT), estimated blood loss (EBL), and renal function impairment [2]. Moreover, a recent comprehensive systematic review and meta-analysis, evaluating the impact of host factors on robot-assisted PN (RAPN), confirmed the ability of both the R.E.N.A.L. and PADUA nephrometry systems to predict the most important intra- and postoperative outcomes [5]. A few studies have compared the PADUA and R.E.N.A.L. nephrometry scores, reporting substantially overlapping ability to predict perioperative outcomes [6,7] and renal function impairment [8]. More recently, Schiavina et al. [9] reported slight advantages in favour of the PADUA classification to predict WIT and major complications.

The first-generation nephrometry systems are clearly imperfect and have limitations such as: interobserver reproducibility, incomplete quantification of relevant anatomical features, and variable correlation with perioperative outcomes. For these reasons, other investigators have proposed and evaluated second-generation nephrometry systems such as: the Diameter-Axial-Polar (DAP) nephrometry system [10], the Zonal Nephro scoring system [11], and Arterial Based Complexity (ABC) scoring system [12]. Moreover, in 2015 Leslie et al. [13] proposed a new imaging parameter to predict the risk of complications after PN: the tumour contact surface area (CSA). Both the available second-generation nephrometry systems and tumour CSA failed to be simpler, more reproducible, or effective than the R.E.N.A.L. and PADUA classifications. Therefore, it is likely that the R.E.N.A.L. and PADUA classifications will remain the most popular in the academic community.

Similarly to TNM staging systems, we believe that the first generation of nephrometry scoring systems should be periodically updated considering the current clinical scenario and the potential role of new imaging features. Indeed, the expanding indications for nephron-sparing surgery, as well as the wide diffusion of laparoscopic approaches and the significant improvement in surgical technique has significantly changed the typology of the tumour treated conservatively and the morbidity of the procedures. Moreover, we need to simplify the available systems to improve their reproducibility and also increase their use in clinical practice, beyond the clinical research setting. For such reasons, 10 years after the introduction of the PADUA score, we performed this multicentre study with the aims of: (i) to simplify our original classification of renal tumours generating a new system able to predict equally or better the risk of overall complications in patients who underwent PN; and (ii) to test if adding the CSA parameter improves the accuracy of the original PADUA and new Simplified PADUA REnal (SPARE) classifications.

Patients and Methods

After local Institutional Review Board approval, we analysed the prospectively collected clinical records of 531 consecutive patients who underwent elective PN because of a suspicion of kidney cancer at five academic, high-volume centres (Brescia, Firenze, Napoli, Torino (Orbassano), and Udine, Italy) from January 2014 to December 2016.

Patient records were extracted from each institutional database. All data were labelled with their respective institution and pooled.

All patients underwent preoperative three-dimensional (3D) abdominal CT scans or abdominal MRI to define the clinical stage and the anatomical characteristics of the tumours. All the radiological images were prospectively evaluated by each participant centre with the aim of assigning each variable (polar location, rim location, exophytic/endophytic rate, renal sinus and urinary collecting system [UCS] involvement, and maximal tumour size) included in the PADUA classification [4], as well as the tumour CSA, according to the formula described by Leslie et al. [13]. The CT protocol included pre- and post-contrast (arterial, venous, excretory phase) images. Slice thickness was 0.5 mm, and volume rendering was performed using the phase (arterial or venous) providing the clearest delineation between the tumour and the surrounding renal parenchyma. Expert and dedicated uro-radiologists calculated the tumour CSA applying 3D-rending software at the preoperative CT scan imaging. Specifically, after measurement of tumour volume and percentage of tumour located within the renal parenchyma, the total surface area (TSA) of the tumour is calculated using the formula $4\pi r^2$ for surface area of a sphere, where r equals tumour radius. The tumour CSA is calculated by multiplying the TSA with the percentage of intraparenchymal component (CSA = TSA × percentage of intraparenchymal tumour/100).

Preoperative staging examination also included: chest imaging (CT or X-ray), serum creatinine, serum electrolytes, and liver function tests. Conversely, bone scan and brain

imaging were performed only when indicated by symptoms. Patients with bilateral renal tumours and/or synchronous metastases were excluded from the present analyses. Moreover, none of the patients received neoadjuvant or adjuvant treatment.

One or two experienced surgeons performed the surgical procedures in each participant centre. In all cases, a traditional PN with the excision of a minimal rim of healthy parenchyma around the capsule or a simple enucleation were performed according to the surgeon's preferences.

For every patient, the following demographic and preoperative variables were extracted from each institutional database: age, gender, body mass index (BMI), Charlson Comorbidity Index (CCI), American Society of Anesthesiologists (ASA) score, clinical tumour size, PADUA classification [4], and tumour CSA [13]. Specifically, according to the original PADUA score, tumours were stratified into low- (score 6–7), intermediate- (score 8–9), and high-risk groups (score ≥10) [4]. The CSA values were categorised in two groups according to the proposed threshold value of 20 cm^2 [13].

Moreover, the following intraoperative variables were recorded: operating room time, WIT, EBL, and transfusion rate. The 3-month postoperative complications were classified according to the modified Clavien–Dindo system [14]. Postoperative complications were distinguished as minor (Grade I–II) and major (Grade III–IV).

Pre- and postoperative estimated GFR (eGFR) was based on serum creatinine and calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula [15]. Renal function was assessed using the most recent eGFR prior to surgery and the eGFR calculated at 3 months after the surgical procedure. Renal function dynamics were represented by the absolute change in eGFR (ACE) and the percentage change in eGFR (PCE). ACE was calculated according the following formula:
$ACE = eGFR_{postoperative} - eGFR_{preoperative}$. PCE was calculated by the formula, $PCE = (eGFR_{postoperative} - eGFR_{preoperative})/eGFR_{preoperative}$. For each patient, the 3-month PCE >20% was calculated.

Excised tumours were staged according to the 2009 version of the TNM classification [16]. Moreover, the following histological features were collected: histological subtypes according to the WHO classification [17], nuclear grade according to the Fuhrman classification [18], and surgical margin (SM) status. Positive SM (PSM) was defined as cancer cells at the level of the inked parenchymal excision surface.

Patients with negative SMs, a WIT <20 min, and without major complications reached the Margin, Ischaemia and Complications (MIC) composite outcome [19].

Statistical Analysis

Parametric continuous variables were reported as mean ± standard deviation (SD), whereas median and interquartile range (IQR) was used for nonparametric continuous variables. The Mann–Whitney *U*-test and the Kruskal–Wallis *H*-test were used to compare two or more nonparametric continuous variables, respectively. The Pearson chi-squared test was used to compare categorical variables.

To simplify the original PADUA classification, the ability of each variable to predict overall complications was tested using binary logistic regression analysis. The variables which were not statistically significant were excluded from the SPARE classification. The odds ratio (OR) values recorded for the variables predicting overall complications were used to assign the new score for each tested category.

In addition to the original PADUA and SPARE systems, two other models were generated adding the score assigned to the CSA categories [13]. Receiver operating characteristic (ROC) curve analysis was used to compare the ability of the four different models to predict overall complications.

Binary logistic regression was used to perform both univariable and multivariable analyses, looking for predictors of overall postoperative complications. Linear regression analysis was used to identify independent predictors of ACE. Beyond the new SPARE nephrometry system, the following preoperative covariates were included in the multivariate models: age, BMI, comorbidities index, preoperative eGFR, and tumour CSA.

For all statistical analyses, a two-sided $P < 0.05$ was considered statistically significant. All data were analysed using the Statistical Package for the Social Sciences (SPSS®), version 23 (SPSS Inc., IBM Corp., Armonk, NY, USA).

Results

Table 1 summarises the preoperative characteristics of 531 patients included in the present study (Table 1). PNs were performed using an open approach in 237 (44.6%) cases, a pure laparoscopic approach in 152 (28.6%), and a robot-assisted approach in the remaining 142 (26.7%). Perioperative and pathological outcomes are reported in Table 2.

At 3 months, postoperative complications were recorded in 140 (26.4%) patients, including 110 (20.7%) with minor and 30 (5.7%) with major complications. Specifically, minor complications were represented by prolonged fever/infection requiring i.v. therapy in 45 (8.4%) patients; haematoma/haematuria requiring blood transfusion in 42 (7.9%); cardiovascular diseases requiring medical therapies in 15 (2.8%); and deep venous thrombosis in eight (1.5%). Major complications included arterio-venous fistula requiring percutaneous embolisation in 18 (3.3%) patients; urinary

Table 1 Demographic, preoperative, and imaging characteristics of the 531 patients included in the analysis.

Variable	Value
Total number of patients	531
Age, years, median (IQR)	64 (55–72)
Male gender, *n* (%)	353 (66.5)
BMI, kg/m^2, median (IQR)	25.7 (23.6–28)
CCI, *n* (%)	
0	416 (78.3)
>0	115 (21.7)
Symptoms at diagnosis, *n* (%)	
Absent	461 (86.8)
Present	70 (13.2)
Clinical tumour size, cm, median (IQR)	3.2 (2.3–4.4)
Polar location, *n* (%)	
Upper	175 (33)
Middle	223 (42)
Lower	133 (25)
Rim location, *n* (%)	
Lateral	315 (59.3)
Medial	216 (40.7)
Renal sinus involvement, *n* (%)	
Absent	393 (74)
Present	138 (26)
UCS involvement, *n* (%)	
Absent	380 (71.6)
Present	151 (28.4)
Exophytic rate (%), *n* (%)	
≥50	251 (47.3)
<50	234 (44.1)
Endophytic	46 (8.7)
Tumour size categories (cm), *n* (%)	
≤4	364 (68.5)
4.1–7	142 (26.7)
>7	25 (4.7)
PADUA score, median (IQR)	8 (7–10)
PADUA risk stratification, *n* (%)	
Low	198 (37.3)
Intermediate	197 (37.9)
High	136 (25.6)
CSA, cm^2, median (IQR)	14.2 (7.4–25.1)
CSA (cm^2), *n* (%)	
≤20	349 (65.7)
>20	182 (34.3)
Preoperative eGFR, mL/min/1.73m^2, median (IQR)	82.2 (66.8–100.4)

Table 2 Intraoperative and pathological features of the 531 patients included in the analysis.

Variable	Value
Total number of patients	531
Approach, *n* (%)	
Open	237 (44.6)
Laparoscopic	152 (28.6)
Robot-assisted	142 (26.7)
Operating room, min, median (IQR)	119 (90–150)
Ischaemia, *n* (%)	
Zero	188 (35.4)
Warm	343 (64.6)
WIT, min, median (IQR) (*n* = 343)	16 (12–20)
EBL, mL, median (IQR)	100 (50–200)
Length of hospital stay, days, median (IQR)	6 (5–7)
Histological subtype, *n* (%)	
Benign	109 (20.5)
Clear cell	293 (55.2)
Non clear cell	129 (24.3)
pT, stage, *n* (%)	
pT1a	274 (64.9)
pT1b	101 (23.9)
pT2	33 (7.8)
pT3a	14 (3.3)
Nuclear grade, *n* (%)	
Grade 1	56 (13.3)
Grade 2	248 (58.8)
Grade 3	99 (23.5)
Grade 4	19 (4.5)
SMs, *n* (%)	
Negative	412 (97.6)
Positive	10 (2.4)
Postoperative eGFR, mL/min/1.73m^2, median (IQR)	81 (64–100)
PCE >20%, *n* (%)	136 (25.6)

leakage requiring ureteric JJ placement in eight (1.5%); and acute renal insufficiency requiring temporary dialysis in four (0.7%).

Table 3 shows the ability of each anatomical and topographic variable to predict the risk of overall complications in univariable analysis. A new score for each category was assigned according to the OR value observed (Table 3).

Figure 1 shows the accuracy of different nephrometry systems generated from the original PADUA classification to predict overall complications (Fig. 1). Specifically, the SPARE score (including (i) rim location; (ii) renal sinus involvement; (iii) exophytic rate; and (iv) tumour dimension) was considered as the simplest, with an AUC value similar to the others (P = 0.9). Moreover, adding the tumour CSA to the original PADUA or SPARE score did not increase the performance of either model (P = 0.8). Notably, the accuracy of tumour size alone was significantly lower than both the PADUA (P = 0.02) and SPARE classification systems (P = 0.03; Fig. 1).

Table 4 reports the most important perioperative outcomes stratified according to the SPARE nephrometry score (Table 4). In detail, overall complications were detected in 63/342 (18.4%) patients in the low-risk group (score 0–3); in 59/152 (38.8%) patients included in the intermediate-risk group (score 4–7); and in 18/37 (48.6%) patients in the high-risk group (score 8–10; P < 0.001). Moreover, the new risk stratification was able to differentiate operative time (P < 0.001), cases not requiring ischaemia (P < 0.001), WIT (P = 0.006), EBL (P < 0.001), and the percentage of patients reaching the MIC composite outcome (P < 0.001; Table 4).

Interestingly, the SPARE system was able to predict the risk of overall complications also in the subgroups of patients treated either by open (P = 0.004), laparoscopic (P < 0.001) or RAPN (P = 0.009). Similarly the SPARE system predicted overall complications in the subgroups of patients who received a simple enucleation (P = 0.002) or a minimal PN (P < 0.001; Table 5).

Multivariable analysis showed that only age (OR 1.0, 95% CI 1.0–1.1) and SPARE nephrometry score (OR 1.2, 95% CI

Table 3 Binary logistic regression analysis shows the accuracy of each anatomical and topographic parameter to predict the risk of overall complications.

Variable	OR (95% CI)	*P*	Score
Polar location			
Upper/lower	Referent		0
Medium	1.3 (0.9–1.9)	0.2	1
Rim location			
Lateral	Referent		0
Medial	1.8 (1.2–2.6)	0.003	2
Renal sinus involvement			
Absent	Referent		0
Present	2.5 (1.6–3.8)	<0.001	3
UCS involvement			
Absent	Referent		0
Present	2.0 (1.3–3.0)	0.001	2
Sinus/UCS involvement			
Absent	Referent		Not applicable
Only UCS	1.6 (0.7–3.3)	0.23	
Only renal sinus	3.6 (1.6–8.1)	0.003	
Both	2.5 (1.6–3.9)	<0.001	
Exophytic rate, %			
≥50	Referent		0
<50	1.3 (0.9–2.0)	0.16	1
Endophytic	2.0 (1.0–3.9)	0.04	2
Maximum tumour size, cm			
≤4	Referent		0
4.1–7	1.8 (1.1–2.7)	0.01	2
>7	3.8 (1.7–8.8)	0.001	4
Tumour CSA, cm^2			
≤20	Referent		0
>20	2.0 (1.3–3.0)	<0.001	2

A new score for each category was assigned according to the reported OR.

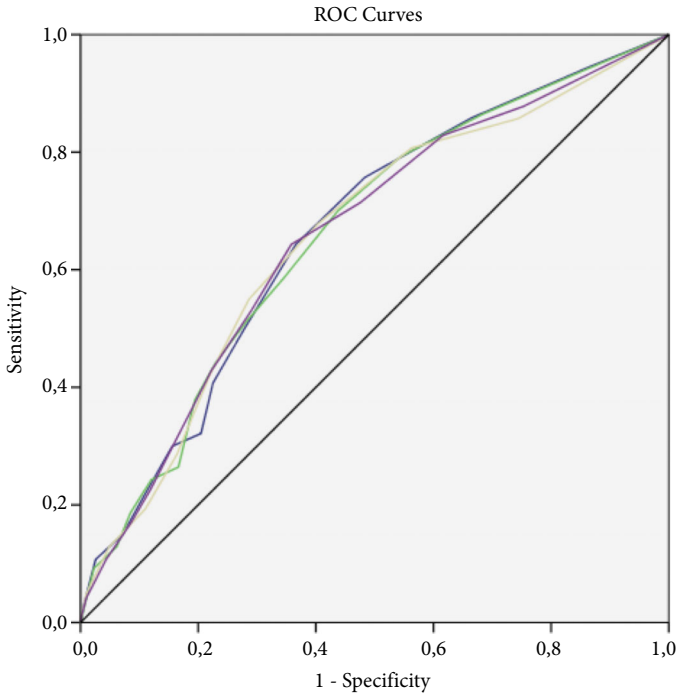
1.1–1.3) were independent predictors of postoperative complications. Table 5 reports the univariable and multivariable analyses identifying the preoperative independent predictors of overall complications (Table 6).

The median (IQR) value of ACE was –6.5 (−18 to +1.5). At 3 months after surgery, 136 (25.6%) patients had a PCE >20%. Linear logistic regression analysis showed that age ($P < 0.001$), BMI ($P < 0.001$), CCI ($P = 0.02$), preoperative eGFR ($P < 0.001$), and tumour CSA ($P = 0.005$), were independent predictors of ACE (Table 7).

Discussion

Rim location, renal sinus involvement, exophytic rate, and tumour size can be combined in a new SPARE nephrometry score able to predict overall complications in patients who undergo PN for renal tumours. Specifically, the SPARE system simplifies the nephrometry score assignment in clinical practice, maintaining the same accuracy of the original PADUA score. Table 8 summarises the variables and scores included in the original PADUA classification compared to those included in the SPARE system (Table 8). Moreover, tumour CSA does not increase the accuracy of either the original PADUA or SPARE score to estimate the risk of complications. However, tumour CSA seems to be more appropriate to predict the 3-month ACE in comparison with the SPARE system.

Fig. 1 ROC curve analysis shows the accuracy (AUC, 95% CI) of different nephrometry systems generated from the original PADUA classification to predict overall complications. The differences between the AUCs were not statistically significant ($P = 0.9$). The accuracy of tumour size was significantly worse compared with the nephrometry system models ($P = 0.02$). Model 1 (blue), original PADUA score: AUC 0.664 (95% CI 0.612–0.715). Model 2 (green), original PADUA score + tumour CSA: AUC 0.661 (95% CI 0.609–0.713). Model 3 (grey), SPARE nephrometry score including rim location, exophytic rate, renal sinus involvement, and tumour size: AUC 0.657 (95% CI 0.604–0.710). Model 4 (violet), SPARE nephrometry score + tumour CSA: AUC 0.658 (95% CI 0.606–0.711). Model 5 (orange), tumour size: AUC 0.57 (95% CI 0.52–0.63).



In the last decade, nephrometry systems have become widely used in clinical practice to estimate the complexity of tumours suitable for PN, and consequently improve the decision-making and patient's counselling processes. Moreover, the introduction of nephrometry systems has increased the quality of clinical research, improving data interpretation and comparison between different series. The R.E.N.A.L. and PADUA nephrometry classifications were proposed in 2009 and represented, together with the Centrality Index, the first-generation of nephrometry score systems [3,4,20].

Both the PADUA and R.E.N.A.L. nephrometry systems communicate geographical location data of the tumour. Conversely, the Centrality Index provides a continuous index based on tumour size and distance from the periphery of the

Table 4 The most important perioperative outcomes are stratified according to the different risk categories identified according to the SPARE nephrometry score.

Variable	Low risk(score 0–3)	Intermediate risk (score 4–7)	High risk(score 8–10)	*P*
Number of patients	342	152	37	
Operating room time, min, median (IQR)	110 (80–140)	130 (100–168)	150 (115–205)	<0.001
No ischaemia, *n* (%)	148 (43.3)	37 (24.3)	3 (8.1)	<0.001
WIT, min, median (IQR)	15 (12–20)	16 (12–21)	19 (15–27)	0.006
EBL, mL, median (IQR)	100 (50–200)	145 (55–300)	200 (100–425)	<0.001
Intraoperative transfusion, *n* (%)	10 (2.9)	3 (2)	0	0.5
Overall postoperative complications, *n* (%)	63 (18.4)	59 (38.8)	18 (48.6)	<0.001
Major (Grade III–IV) postoperative complications	12 (3.5)	15 (9.9)	3 (8.1)	0.01
MIC reached, *n* (%)	258 (75.4)	87 (57.2)	15 (40.5)	<0.001
ACE, mL/min/1.73m^2, median (IQR)	−6 (−15 to 0.02)	−7.3 (−21.7 to 5.6)	−10 (−26 to 2.3)	0.6

Table 5 Correlation between the SPARE nephrometry score and presence of overall complications stratified according to surgical approach and technique.

Variables	Number of patients	SPARE value, median (IQR)	*P*
Open PN (*n* = 237)			
No complication	162	2 (1–5)	0.004
Complications	75	4 (2–5)	
Laparoscopic PN (*n* = 152)			
No complication	109	2 (1–3)	<0.001
Complications	43	3 (2–6)	
RAPN (*n* = 142)			
No complication	120	1 (0–4)	0.009
Complications	22	4 (1–7)	
Simple enucleation (*n* = 136)			
No complication	109	1 (0–2)	0.002
Complications	27	3 (0–5)	
Minimal PN (*n* = 395)			
No complication	282	2 (1–5)	<0.001
Complications	113	4 (2–6)	

tumour to the centre of the kidney. Available studies included in a review published in 2015, showed that the R.E.N.A.L. nephrometry score and PADUA classification were the most popular and used in comparison to the Centrality index. Interestingly, validation studies of these first-generation nephrometry systems showed conflicting results, probably as consequence of the heterogeneity of the evaluated series [2]. More recently, Cacciamani et al. [5] performed a systematic review and meta-analysis of the literature including all surgical series and comparative studies involving patients treated by RAPN. When the reviewed series were stratified according to the R.E.N.A.L. nephrometry score, complex cases showed longer operative time and WIT; higher EBL and overall complications in comparison with less complex cases. Conversely, the R.E.N.A.L. nephrometry score failed to identify any difference between low- and high-complexity tumours in terms of transfusion rate, major complications, length of hospital stay, renal function, and PSM rates. Similarly, the PADUA score stratified appropriately low- and high-complexity cases in terms of all previous perioperative outcomes with the exception of renal function and PSM rate.

Interestingly, for the first time, our present study showed that the accuracy of the original PADUA classification was not diminished by removing some features such as polar location and UCS involvement. The polar location was removed because it was not predictive of overall complications in univariable analysis. Similarly, clustering together in a single variable the renal sinus and UCS involvement, we observed that cases with only UCS involvement were similar to those cases with any involvement. Therefore, UCS involvement was removed from the system. Consequently, the new SPARE system should be easier to calculate, considering that the polar location and the UCS involvement are two time-consuming steps of the original PADUA score. Dedicated studies analysing the inter- and intra-observer concordance of the original PADUA and SPARE score will be needed to confirm such a hypothesis.

All the variables included in the new SPARE system were already present in the R.E.N.A.L. nephrometry system, with the exception of the tumour location at the level of the medial or lateral rim of the kidney [3]. Indeed, the exophytic rate and the tumour size are stratified using the same threshold values and the categories identified by the variable '(N)earness to the collecting system or sinus' can be easily modified to the absence (≥4 mm) or presence (<4 mm) of renal sinus involvement according to the SPARE system.

Other preoperative imaging features have recently been proposed in the literature beyond the parameters included in the R.E.N.A.L. and PADUA systems. In this context, tumour CSA is the most extensively investigated and has been externally validated [13,21,22]. For the first time, our present study showed that the addition of tumour CSA to the original PADUA score or to the SPARE system did not increase their accuracy in predicting overall complications. However, our present study confirmed the role of tumour CSA as an independent predictor of renal function impairment in a model adjusted for all the most important patient-related factors such as: age, BMI, CCI, and preoperative eGFR. Conversely, the SPARE system was not an independent predictor of renal function impairment. These data concur with other studies showing that the original PADUA score was not a predictor of 3-month renal function impairment [5,23]. Therefore, tumour CSA could help surgeons to tailor

Table 6 Univariable and multivariable analyses to predict overall postoperative complications.

Variables	Univariable analysis		Multivariable analysis	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Gender				
Male	Referent	0.7		
Female	0.9 (0.6–1.4)			
Age (continuous)	1.0 (1.0–1.1)	0.001	1.0 (1.0–1.1)	<0.001
BMI (continuous)	1.0 (0.9–1.1)	0.2	1.0 (0.9–1.1)	0.3
CCI score				
0–1	Referent	0.8	Referent	
>1	1.1 (0.7–1.6)		1.0 (0.6–1.6)	0.9
Symptoms				
Absent	Referent	0.30		
Present	1.3 (0.8–2.3)			
Clinical tumour size (continuous)	1.0 (1.0–1.1)	<0.001		
Preoperative eGRF (continuous)	1.0 (0.9–1.1)	0.1	1.0 (0.9–1.0)	0.8
SPARE* score	1.2 (1.1–1.3)	<0.001	1.2 (1.1–1.3)	<0.001
SPARE* risk				
Low (score 0–3)	Referent			
Intermediate (score 4–7)	2.8 (1.8–4.3)	<0.001		
High (score 8–10)	4.2 (2.1–8.4)	<0.001		
Tumour CSA (continuous)	1.1 (1.0–1.1)	<0.001	1.1 (1.0–1.1)	0.2
Tumour CSA, cm^2				
≤20	Referent			
>20	2.0 (1.4–3.0)	<0.001		

**SPARE nephrometry system including rim location, exophytic rate, renal sinus involvement, and tumour size.*

Table 7 Multivariable (linear regression analysis) analysis to identify independent predictors of ACE.

Variables	*B* (95% CI)	*P*
Age (continuous)	−0.114 (−0.6 to −0.3)	<0.001
BMI (continuous)	0.06 (0.3 to 1.1)	0.001
CCI score (continuous)	−0.046 (−3.1 to −0.2)	0.02
Preoperative eGFR (continuous)	−0.924 (−0.9 to −0.8)	<0.001
SPARE* score (continuous)	0.02 (−0.4 to 1.2)	0.4
Tumour CSA (continuous)	−0.06 (−0.3 to−0.05)	0.005

**SPARE nephrometry system including rim location, exophytic rate, renal sinus involvement, and tumour size.*

Table 8 Comparison between the original PADUA classification and new SPARE nephrometry system.

Variables	Original PADUA score	SPARE score
Polar location		
Upper/lower	1	Not included
Medium	2	
Rim location		
Lateral	1	0
Medial	2	2
Renal sinus involvement		
Absent	1	0
Present	2	3
UCS involvement		
Absent	1	Not included
Present	2	
Exophytic rate, %		
≥50	1	0
<50	2	1
Endophytic	3	2
Maximum tumour size, cm		
≤4	1	0
4.1–7	2	2
>7	3	4

the most appropriate dissection strategy, e.g., preferring simple enucleation instead of a wider resection of healthy parenchyma in patients with CSA values >20 cm^2.

Limitations of the present study include the retrospective design and the lack of central imaging review to assign the variables included in the PADUA score and to calculate the tumour CSA. Moreover, we did not calculate the amount of healthy parenchyma sacrificed during the extirpative phase of the procedure applying specific formulas based on the pre- and postoperative imaging or measuring the rim of healthy parenchyma around the tumour on the surgical specimens. However, in all cases the authors' minimised the excisional volume loss, performing a simple enucleation or a minimal PN. Last, similarly to the imaging features, the pathology slides review was not centralised. The lack of a validation is a further limitation of the study. Obviously, the SPARE system needs to be externally validated in the context of further single and multicentre studies.

Conclusions

Today, 10 years after the proposal of the original PADUA score, based on six anatomical and topographic tumour-related features, we propose a new simplified version of this nephrometry system (SPARE) to predict the risk of postoperative complications. Only four features (rim location, renal sinus involvement, exophytic rate, and maximum tumour size) comprise the new SPARE nephrometry score.

The accuracy of the new SPARE system was similar to that recorded for the original PADUA score and was not increased by the addition of the tumour CSA parameter. The SPARE nephrometry score correlated with all the most important perioperative outcomes and was an independent predictor of overall complications. Interestingly, the new SPARE system was generated from a multi-surgeon, multicentre series including >50% of cases performed via a minimally invasive approach. Moreover, ~30% of patients had PN for tumours >4 cm. For those reasons, the SPARE system could replace the original PADUA score to evaluate the complexity of tumours suitable for nephron-sparing surgery. Obviously, large, multicentre studies are needed to obtain an external validation of this new SPARE nephrometry system. Interestingly, the tumour CSA was confirmed to be an important predictor of renal function impairment together with the most relevant patient-related factors.

Conflict of Interest

None disclosed.

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Abbreviations: ACE, absolute change in eGFR; AUC, area under the curve; BMI, body mass index; CCI, Charlson Comorbidity Index; CSA, contact surface area; 3D, three-dimensional; EBL, estimated blood loss; eGFR, estimated GFR; IQR, interquartile range; MIC, Margin, Ischaemia and Complications (composite outcome); OR, odds ratio; PADUA, Preoperative Aspects and Dimensions Used for an Anatomical; PCE, percentage change in eGFR; (RA)PN, (robot-assisted) partial nephrectomy; R.E.N.A.L, Radius Exophytic/Endophytic Nearness Anterior/Posterior Location (nephrometry score); ROC, receiver operating characteristic; (P)SM, (positive) surgical margin; SPARE, Simplified PADUA REnal (nephrometry score); TSA, total surface area; WIT, warm ischaemia time; UCS, urinary collecting system.